Questions and answer for Set- 1

Section -A

1. Suggest two methods by which method the range of transmission by a TV tower can be increased
Answer:- (a) By increasing height of Antenna.
(b) By using communication satellite.
2. Two wires of equal length, one of copper and other of the manganin have the same resistance. Which wire is thicker?
Answer:- Manganin.
3. The energy of the hydrogen atom in its ground state is –13.6 eV. Calculate the energy of the atom in the second excited state.
Answer:-
$\because E_n = \frac{-13.6\ eV}{n^2}$ $\therefore E_2 = \frac{-13.6\ eV}{2^2} = -3.4$ eV
4. What is the threshold frequency of a photon for photoelectric emission from a metal of work function 0.1 eV?
Answer:-
$\because W_0 = h\nu_0$ $\therefore \nu_0 = \frac{W_0}{h} = \frac{0.1\ eV}{6.63 \times 10^{-34}\ Js} = \frac{0.1 \times 1.6 \times 10^{-19}\ J}{6.63 \times 10^{-34}\ Js} = 0.024 \times 10^{15}$ Hz = 2.4×10^{13} Hz
5. Two lenses of power +4 and –2 dioptres respectively are placed 10 cm apart. What is focal length and power of the combination?
Answer:-
Power of equivalent lens $P = P_1 + P_2 = 4 - 2 = 2$ D
$\therefore$ Focal length of equivalent lens $F = \frac{1}{P} = \frac{1}{2} = 0.5$ m = 50 cm.

Section – B

6. Calculate the temperature at which the resistance of a conductor becomes 20% more than its resistance at 27^0C. The value of the temperature coefficient of resistance of the conductor is 2×10^{-4}/K.
Answer:-
Given temperature coefficient of resistance $\alpha = 2 \times 10^{-4}\ K^{-1}$
Let resistance at $T_1 = 27^0$ is $R_1 = R$
$\therefore$ Resistance at unknown temperature T_2 is $R_2 = R + 20\%$ of $R = R + 0.20R = 1.20R$

$\because R_2 = R_1 [\ 1 + \alpha\ (T_2 - T_1)]$ Or $1.20\ R = R\ [\ 1 + 2\times 10^{-4}\ (T_2 + 27)]$
Or $1.20 = 1 + 2\times 10^{-4}\ (T_2 + 27)$ Or $1.20 - 1 = 2\times 10^{-4}\ (T_2 + 27)$
Or $T_2 + 27 = \frac{0.20}{2\times10^{-4}} = 0.10 \times 10^4 = 1000$
$\therefore T_2 = 1000 - 27 = 973^0$ C
7. Drive an expression for amplitude modulated wave.
Answer:-

When amplitude of carrier wave is varied in accordance with amplitude of information signal then modulation is called amplitude modulation and obtained resultant wave is called amplitude modulated wave.

Let when a modulating signal $m(t) = A_m \sin \omega_m t$ is superimposed on carrier wave $C(t) = A_C \sin \omega_C t$, then amplitude modulated wave obtains.

The modulated wave or signal $C_m(t)$ can be written as,

$$C_m(t) = (A_C + A_m \sin \omega_m t) \sin \omega_C t$$

$$= A_C \left(1 + \frac{A_m}{A_c} \sin \omega_m t\right) \sin \omega_C t$$

$$= A_C \sin \omega_C t + \frac{A_m}{A_c} \sin \omega_m t \sin \omega_C t$$

$$= A_C \sin \omega_C t + \mu \sin \omega_m t \sin \omega_C t \quad \ldots\ldots\ldots\ldots\ (i)$$

where $\mu = \frac{A_m}{A_c}$ is called modulation index.

Using the trignomatric relation $2\sin A . \sin B = \cos(A - B) - \cos(A + B)$, equation (i) can be written as,

$$C_m(t) = \tfrac{1}{2}\left[A_C \sin \omega_C t + \frac{\mu A_C}{2} \cos(\omega_C - \omega_m) t - A_C \sin \omega_C t + \frac{\mu A_C}{2} \cos(\omega_C + \omega_m) t\right.$$

8. A T.V. tower has a height of 400 m at a given place. Calculate as coverage range, if the radius of the earth is 6400 km.

Answer:-

Given, height of antenna $h = 400$ m, Radius of the earth $R = 6400$ km $= 6.4 \times 10^6$ m,
Coverage area $A = ?$

$\therefore A = \pi d^2 = \pi \left(\sqrt{2Rh}\right)^2 = \pi \times 2Rh = 3.14 \times 2 \times 6.4 \times 10^6 \times 400 = 16076.8 \times 10^6 \ m^2$
$= 16076.8 \ km^2$

9. Name the reaction which takes place when a slow neutron beam strikes ${}_{92}U^{235}$ nuclei. Write the nuclear reaction involved.

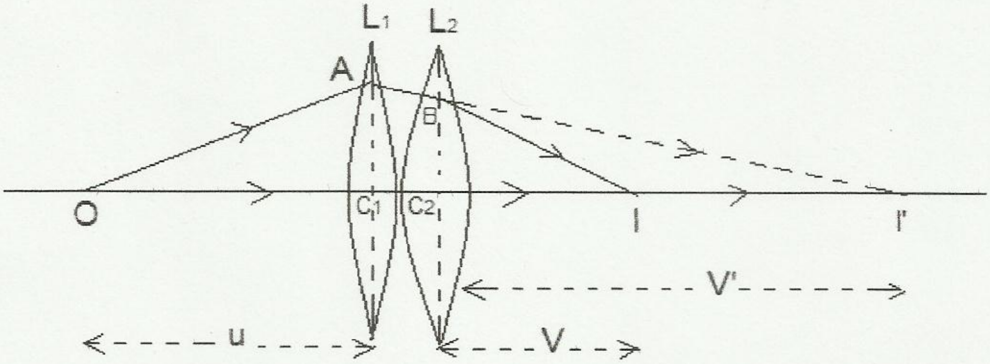
Answer:-

Nuclear fission

${}_0n^1 + {}_{92}U^{235} \ {}_{56}Ba^{144} + {}_{36}Kr^{89} + 3\ {}_0n^1 + 200$ MeV

10. Obtain an expression for the effective focal length of two thin lenses placed in contact coaxially with each other.

Ans:



Consider two thin lenses L_1 and L_2 of optical centre C_1 and C_2 placed in air co-axially. The focal lengths of lenses are f_1 and f_2 respectively. A pointed object O is placed on the principal axis. In absence of lens L_2 real image of O would form at I' and in presence of lens L_2 final real image would form at I.

Now, from lens formula for lens L_1 ,

$$\frac{1}{V'} - \frac{1}{u} = \frac{1}{f_1} \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{(i)}$$

Similarly, from lens formula for lens L_2 ,

$$\frac{1}{V} - \frac{1}{V'} = \frac{1}{f_2} \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{(ii)}$$

Adding equation (i) and (ii), we get,

$$\frac{1}{V} - \frac{1}{u} = \frac{1}{f_1} + \frac{1}{f_2} \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{(iii)}$$

If equivalent focal length of L_1 and L_2 is F, then from lens formula,

$$\frac{1}{V} - \frac{1}{u} = \frac{1}{F} \quad \ldots\ldots\ldots\ldots\ldots \text{(iv)}$$

Comparing equation (iii) and (iv),

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} \quad \ldots\ldots\ldots\ldots \text{(v)}$$

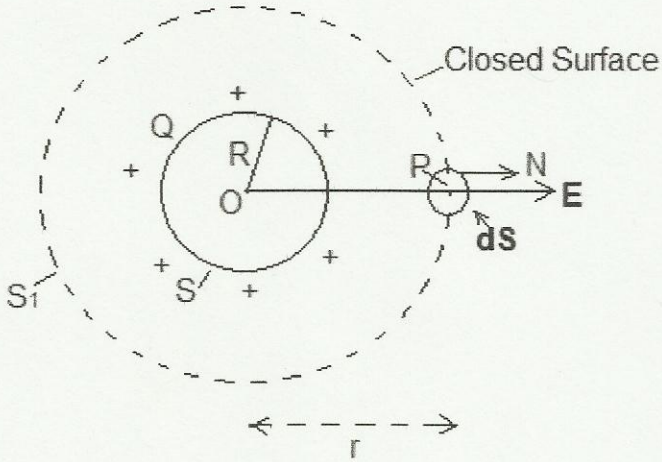
Section – C

11. State Gauss' theorem in electrostatics. Using this theorem, derive the expression for the electric field intensity at any point outside a uniformly charged thin spherical shell.

Ans:

Gauss' theorem: The total electric flux linked with a closed surface is $\frac{1}{\varepsilon_0}$ times of net charge in closed inside closed surface.

i.e. $\phi_E = \oint_S \vec{E} \, . \, \overrightarrow{dS} = \dfrac{Q}{\varepsilon_0}$



Consider a charged spherical shell of radius R placed in air vacuum. Let we have to determine electric field intensity at point P outside the shell at distance r from centre O. For this we imagine a spherical closed surface S_1 of radius r such that point P is on the surface of S_1. The electric field at every point on the surface of S_1 is **E** directed outside along radius. Let surface S_1 is divide into many equal parts of area dS. Again consider one area element **dS** .

Now, total electric flux linked with closed surface S_1 will,

$$\phi_E = \oint \vec{E}\,.\overrightarrow{dS} = \oint EdS\cos\theta = \oint EdS\cos 0^0 = \oint E\, dS = \mathrm{E}\oint dS$$

$= \mathrm{E} \times$ total area of closed surface S_1

$\phi_E = \mathrm{E} \times 4\pi\, \mathrm{r}^2$ .... (i)

According to Gauss' theorem, $\phi_E = \dfrac{Q}{\varepsilon_0}$ ....(ii)

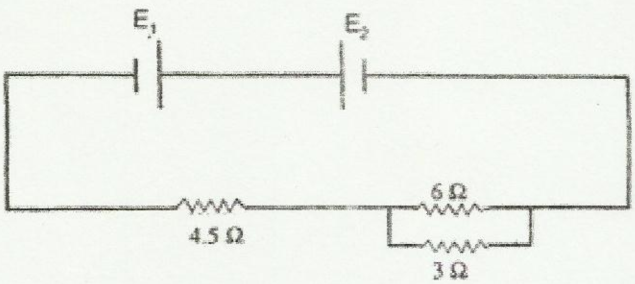
Comparing equations (i) and (ii),we gwt

$\mathrm{E} \times 4\pi\, \mathrm{r}^2 = \dfrac{Q}{\varepsilon_0}$

$\therefore\quad \mathrm{E} = \dfrac{Q}{4\pi\varepsilon_0 r^2}$ .... (iii)

This equation is same as electric field intensity due to a point charge. Hence charged spherical shell can be assumed as a point charge.

12. Two cells E_1 and E_2 in the given circuit diagram have an emf of 5 V and 9 V and internal resistance of 0.3Ω and 1.2Ω respectively. Calculate the value of current flowing through the resistance of 3Ω.



Ans:

Equivalent resistance of resistors 6 Ω and 3 Ω will $R_1 = \frac{6 \times 3}{6+3} = \frac{18}{9} = 2\ \Omega$

R_1 is connected in series with resistor 4.5 Ω

∴ Equivalent resistance of R_1 and 4.5 Ω will $R = R_1 + 4.5\ \Omega = 2 + 4.5\ \Omega = 6.5\ \Omega$

Effective emf of both cells will $E = -E_1 + E_2 = -5\ V + 9\ V = 4\ V$

∴ Total current in circuit $I = \frac{E}{R} = \frac{4}{6.5} = \frac{40}{65} = \frac{8}{13}$ A

∴ Voltage across R_1 will $V_1 = I R_1 = \frac{8}{13} \times 6.5 = 4\ V$

∴ current through resistor of 3 Ω $= \frac{V_1}{3} = \frac{4}{3} = 0.75$A

13. State the principle of working of p-n diode as a rectifier. Explain, with the help of a circuit diagram, the use of p-n diode as a full wave rectifier. Draw a sketch of the input and output waveforms

Ans:-

Principle of working of diode as rectifier:- **When diode is in forward bias, then current flows through diode and when diode is in reverse bias, then current does not flow through the diode.**

Use of diode as full wave rectifier:-

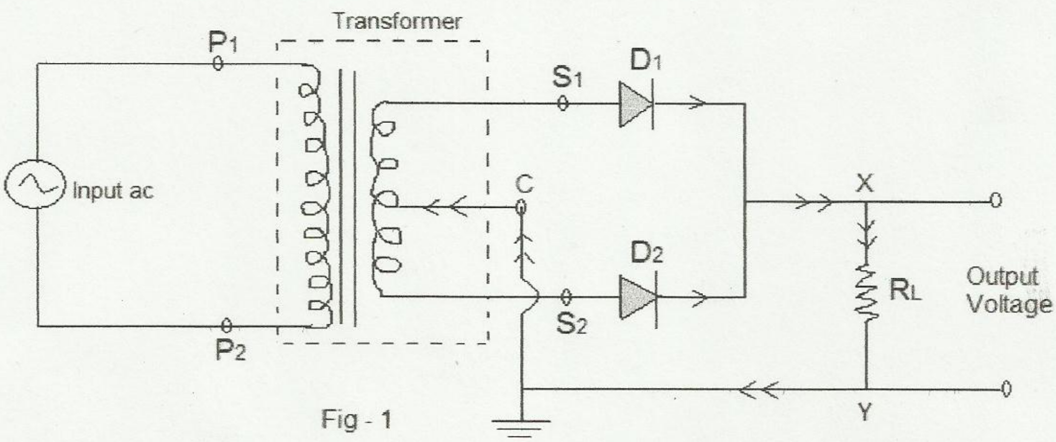


Fig - 1

The circuit diagram of use of diode as ful wave rectifier is shown in the figure -1.

Working:- when positive half cycle of A.C. reaches at S_1, then same time negative half cycle reaches at S_2. In this situation diode D_1 is in forward bias and diode D_2 is in reverse bias. Therefore, current flows through the diode D_1 and load resistor R_L in the centre tap C. Again when negative half cycle of A.C. reaches at S_1, then same time positive half cycle reaches at S_2. In this situation diode D_1 is in reverse bias and diode D_2 is in forward bias. Therefore, current flows through the diode D_2 and load resistor R_L in the centre tap C.

Thus, this circuit rectify full wave of A.C. and is called full wave rectification.

The obtained input and output wave form by this circuit are shown in the figure -2.

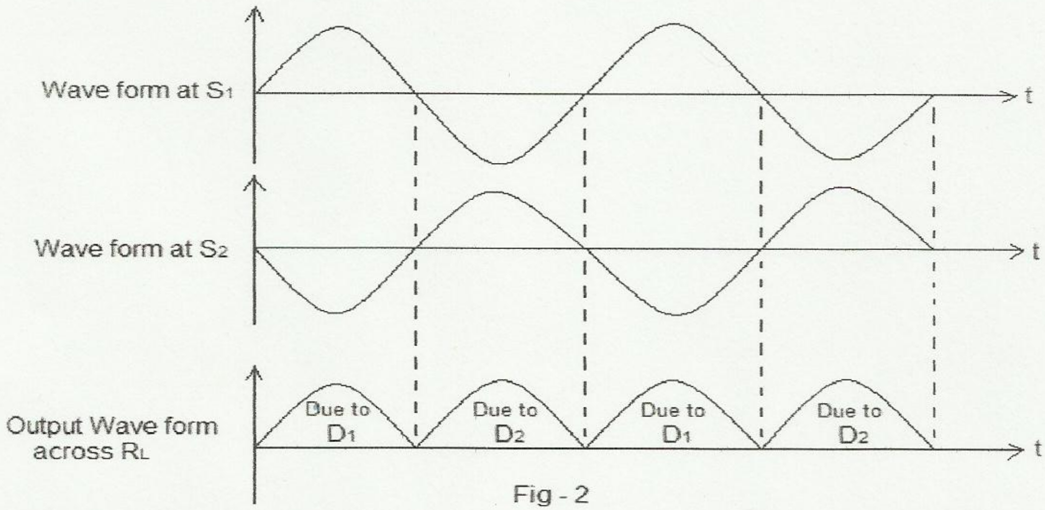


Fig - 2

14. What do understand by Electromagnetic wave ? How does a charge q oscillating at certain frequency produce electromagnetic wave ? Give its four properties.

Ans:- those waves in which electric and magnetic field vector are sinusoidal vary at right angle to each other as well as right angle to the direction of propagation of wave, are called electromagnetic wave.

It is an important result of Maxwell's theory that accelerated charges or oscillating charge radiate electromagnetic waves. This produces an oscillating electric field in space, which produces an oscillating magnetic field, which is a source of oscillating electric field, and so on. Thus the oscillating electric and magnetic fields regenerate each Other which propagates through the space in the form of electromagnetic waves. The frequency of the electromagnetic wave naturally equals the frequency of oscillation of the charge.

Four properties of electromagnetic waves:

(i) These are produce by accelerating or oscillating charge.

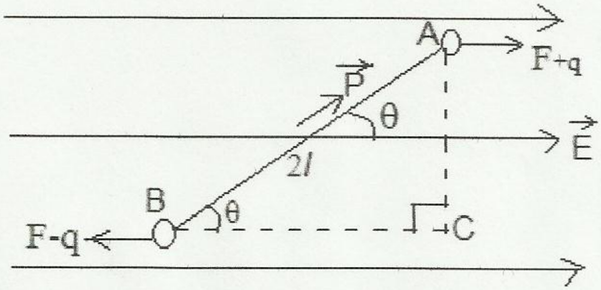
(ii) Material medium is not required for propagation of electromagnetic wave.

(iii) These wave carry energy which is divided equally between electric and magnetic field vectors.

(iv) These wave are not deflected by electric and magnetic fields.

15. An electric dipole is held in an uniform electric field (i) suitable diagram show that it does not undergo any translatory motion, and (ii) derive an expression for torque acting on it and specify its direction.

Answer:



According to figure, electric force on charge +q of electric dipole due to uniform electric field will,

$F_{+q} = qE$ [along $\vec{E}$]

And Electric force on charge -q of electric dipole due to uniform electric field will,

$F_{-q} = -qE$ [opposite to $\vec{E}$]

∴ Net force on dipole $F = F_{+q} + F_{-q} = qE - qE = 0$

Hence electric dipole will not done translator motion.

But action lines of forces F_{+q} and F_{-q} are different. So, dipole will want to rotate.

Torque acting on the dipole will,

τ = magnitude of either force × perpendicular distance between forces.

$= qE \times AC = qE \times AB \sin\theta$ [From triangle ABC, $\sin\theta = \frac{AC}{AB} \Rightarrow AC = AB \sin\theta$]

$= qE \times 2l \sin\theta = 2ql\,(E \sin\theta)$

$= PE \sin\theta$

$\therefore \tau = PE \sin\theta$ .... (i)

In vector form $\vec{\tau} = \vec{P} \times \vec{E}$ .... (ii)

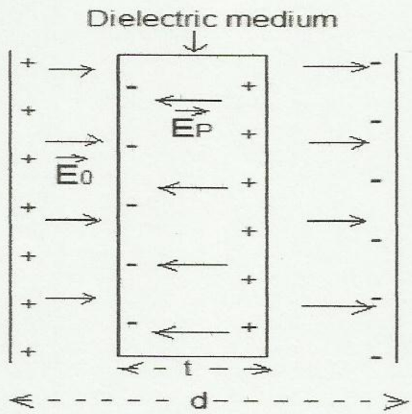
Direction of torque:- Direction of torque will be perpendicular to the plane of paper directed downwards.

16. Briefly explain the principle of a capacitor. Derive an expression for the capacitance of a parallel plate capacitor, whose plates are separated by a dielectric medium.

Answer:

Principle of capacitor:- when an earthed conductor plate is brought near unearthed conductor, then capacitance of unearthed conductor is increased extemly.

Expression for capacitance of parallel plate capacitor whereas dielectric medium of thickness t is placed in between plates



Suppose a dielectric medium of permittivity K and thickness t is placed in between plates of capacitor, where t < d.

$\therefore\ K = \frac{E_0}{E} \Rightarrow E = \frac{E_0}{K}$ ..... (iv)

Where E = electric field in dielectric medium and E_0 = electric field in air.

$\therefore$ Potential difference between plates will, $V = V_{air} + V_{dielectric}$

$\Rightarrow V = E_0\,(d-t) + E\,t = E_0\,(d-t) + \frac{E_0}{K}t$ [From equation (iv)]

$\Rightarrow V = E_0\,[\,d - t + \frac{t}{K}\,] = \frac{\sigma}{\varepsilon_0}\,[\,d - t + \frac{t}{K}\,]$

$\Rightarrow V = \frac{q}{\varepsilon_0 A}\,[\,d - t + \frac{t}{K}\,]$ .... (v)

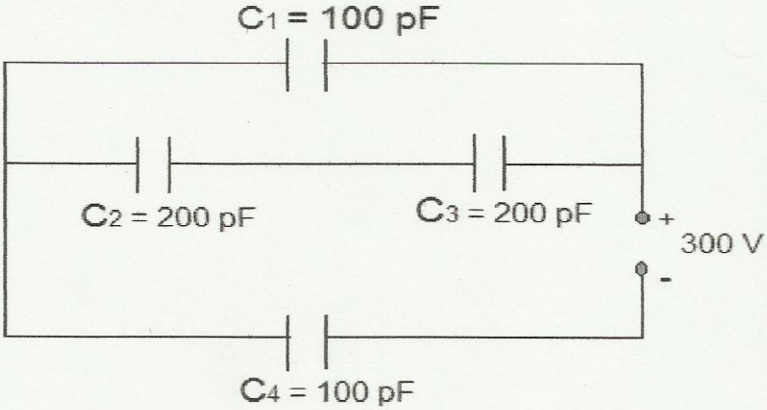
$\therefore$ Capacitance of capacitor will,

$$C = \frac{q}{V} = \frac{q}{\frac{q}{\varepsilon_0 A}[\,d - t + \frac{t}{K}\,]} = \frac{\varepsilon_0 A q}{q[\,d - t + \frac{t}{K}\,]} = \frac{\varepsilon_0 A}{d - t + \frac{t}{K}}$$

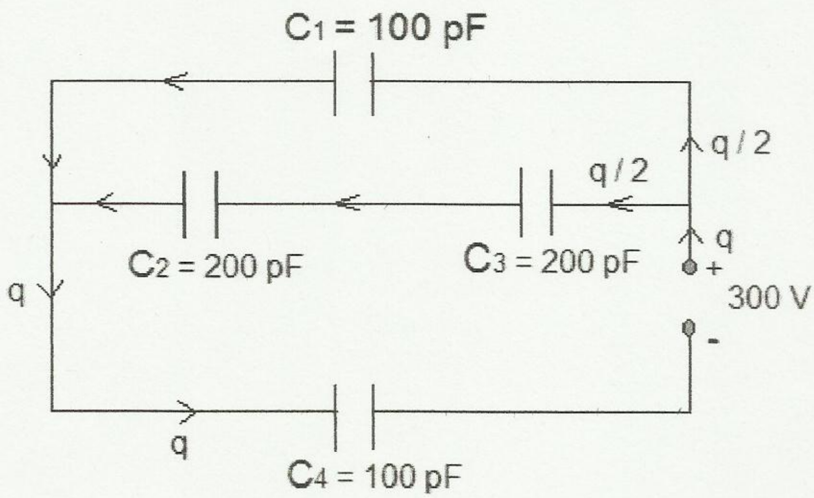
$$\Rightarrow C = \frac{\varepsilon_0 A}{d - t\,(1 + \frac{1}{K})}$$ .... (v)

Or

Obtain equivalent capacitance of the following network given in the figure below. For a v 300 V supply, determine the charge and voltage cross each capacitor.



Ans:-



Equivalent capacitance of C_2 and C_3 is $C_{23} = \frac{C_2 . C_3}{C_2 + C_3} = \frac{200 \times 200}{200+200} = \frac{200 \times 200}{2 \times 200} = 100$ pF

C_{23} is connected with capacitor C_1 in parallel.

Therefore, equivalent capacitance of C_{23} and C_1 will,

$C_{123} = C_{23} + C_1 = 100$ pF + 100 pF = 200 pF

Again, C_{123} is connected with C_4 in series. Therefore, equivalent resistance of Circuit will $C = \frac{C_{123} \times C_4}{C_{123} + C_4} = \frac{200 \times 100}{200+100} = \frac{200 \times 100}{300} = \frac{200}{3}$ pF

Charge flowing in the circuit will,

$q = CV = \frac{200}{3}$ pF $\times$ 300 V $= \frac{200}{3} \times 10^{-12} \times 300$ V $= 2 \times 10^{-8}$ coulomb

Since charge does not distribute in series,

$\therefore$ Charge on each plate of C_{123} and $C_4 = 2 \times 10^{-8}$ coulomb

i.e. $q_{123} = q_4 = 2 \times 10^{-8}$ coulomb

Again, Charge distribute equally in parallel , when they are of equal capacitances

∴ Charge on each plate of C_1 and C_{23} = $\frac{q}{2} = \frac{2 \times 10^{-8}}{2} = 10^{-8}$ coulomb

i.e. $q_1 = q_2 = q_3 = 10^{-8}$ coulomb

Now, voltage across C_1 will $V_1 = \frac{q_1}{C_1} = \frac{10^{-8}}{100 \times 10^{-12}} = 100$ volt

voltage across C_2 will $V_2 = \frac{q_2}{C_2} = \frac{10^{-8}}{200 \times 10^{-12}} = 50$ volt

voltage across C_3 will $V_3 = \frac{q_3}{C_3} = \frac{10^{-8}}{200 \times 10^{-12}} = 50$ volt

voltage across C_4 will $V_4 = \frac{q_4}{C_4} = \frac{2 \times 10^{-8}}{100 \times 10^{-12}} = 200$ volt

17. Define the terms: 'half-life period' and 'decay constant' of a radioactive sample. Derive the relation between these terms.

Answer:

Decay constant:- the reciprocal of time at the end of which the number of atoms left undecayed in a radioactive sample reduces $\frac{1}{e}$ time the original number of atoms (N_0) in the sample.

Half-life period:- The time during which number of atoms left undecayed in the sample is half the total number of atoms present initially in the sample.

When t = T , $N = \frac{N_0}{2}$

∴ from relation $N = N_0 e^{-\lambda t}$,

$\frac{N_0}{2} = N_0 e^{-\lambda t} \Rightarrow \frac{1}{2} = e^{-\lambda t} \Rightarrow 2 = e^{\lambda t}$

Taking log both sides ,

$\log_e 2 = \log_e e^{\lambda t} \Rightarrow \lambda t \log_e e = \log_e 2 \Rightarrow \lambda t = 2.3026 \log_{10} 2$

18. What is total internal reflection? What are conditions for it? Explains any one of its practical application.

Answer:

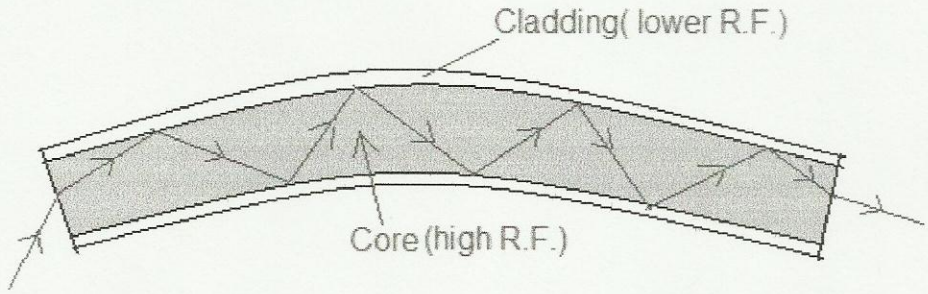
Total internal reflection:- When light passes from a denser medium to rarer medium at an angle greater than critical angle , then total part of light reflect in denser medium according to rule of reflection of light. This phenomenon of light is called total internal reflection of light.

Conditions:- (i) light should be passes a denser medium rarer medium,

(ii) The angle of incident should be greater than critical angle.

Its one Practical application:-

Optical fibre:



Optical fibre work on the principle of total internal reflection. Optical fibres are fabricated with high quality composite glass/quartz fibres. Each fibre consists of a core and cladding. The refractive index of the material of the core is higher than that of the cladding. When a signal in the form of light is directed at one end of the fibre at a suitable angle (greater than critical angle of diamond with air), it undergoes repeated total internal reflections along the length of the fibre and finally comes out at the other end. During this there is no loss in the intensity of the light signal. Even if the fibre is bent, light can easily travel along its length.

19. (a) Using Bohr's postulates, obtain the expression for total energy of the electron in the n^{th} orbit of hydrogen atom.

(b) What is the significance of negative sign in the expression for the energy?

Answer:

(a) Bohr's radius of orbit and total energy of orbital electron in hydrogen atom

From Bohr's Second Postulate, $mvr = \frac{nh}{2\pi} \Rightarrow v = \frac{nh}{2\pi mr}$ .... (i)

The centripetal force required for revolution of electron in orbit is provided by the electrostatic force of attraction between electron and the nucleus.

$\therefore\ F_c = F_e$

$\Rightarrow \frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$

$\Rightarrow \frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{(e)(Ze)}{r^2}$

$\Rightarrow \frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r^2}$ .... (ii)

$$\Rightarrow \quad \frac{m}{r}\left(\frac{nh}{2\pi mr}\right)^2 = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r^2} \quad \text{[From Eq}^n\text{ (i)]}$$

$$\Rightarrow \quad \frac{mn^2h^2}{4\pi^2m^2r^3} = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r^2}$$

$$\Rightarrow \quad \frac{n^2h^2}{\pi mr} = \frac{Ze^2}{\varepsilon_0}$$

$$\Rightarrow r = \frac{\varepsilon_0 n^2h^2}{\pi Zme^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(iii)}$$

For hydrogen atom Z = 1

$$\therefore \; r = \frac{\varepsilon_0 n^2h^2}{\pi me^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(iv)}$$

Total energy of orbital electron in hydrogen atom

The energy of electron revolving in a stationary orbit is of two type:
Kinetic energy which is due to velocity and potential energy which due to position of electron,

Therefore total energy of electron, E = K.E + P.E ………… (v)

From equation (ii)

$$\Rightarrow mv^2/r = K\,Ze^2/r^2$$

$$\Rightarrow mv^2 = K\,Ze^2/r$$

$$\Rightarrow mv^2/2 = K\,Ze^2/2r$$

$$\therefore \text{K.E of electron} = \frac{1}{2}mv^2 = \frac{KZe2}{2r} \quad \ldots\ldots\ldots \text{(vi)}$$

Again Potential energy of electron,

$$\text{P.E} = \frac{K\,q_1q_2}{r} = \frac{K\,(-e)\,(Ze)}{r} = \frac{-K\,Ze^2}{r} \quad \ldots\ldots \text{(vii)}$$

$$\therefore \text{ Total energy of electron, E} = \text{K.E} + \text{P.E} = \frac{KZe2}{2r} - \frac{K\,Ze2}{r} = \frac{-\,KZe2}{2r} \quad \ldots\ldots \text{(viii)}$$

Putting $r = \frac{n2h2}{4\pi 2\ mKZe2}$ in equation (viii), we get $E = \frac{-2\,\pi^2mK^2Z^2e^4}{n^2h^2}$ ……… (ix)

(b) In the equation (ix) negative sign indicates that electron is bound to the nucleus i.e. the electron is not free to leave orbit around the nucleus.

20. State the principle of potentiometer. Draw a circuit diagram used to compare the e.m.f. of two primary cells. Write the formula used. How can the sensitivity of a potentiometer be increased?

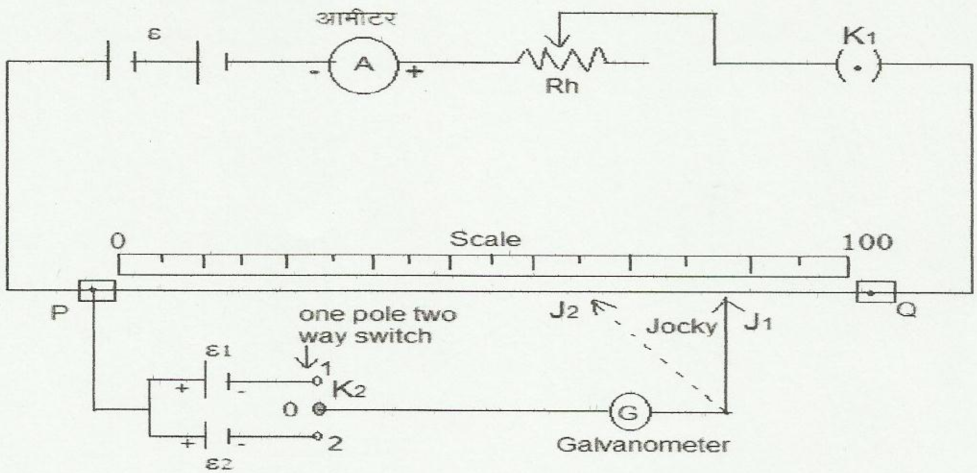
Answer:

Principle of potentiometer:- If constant current flow through a wire of uniform cross sectional area, then potential drop across a part of wire is directly proportional to the length of that part.

i.e. $V \propto l \Rightarrow V = Kl$ .... (i)

Where K is a constant which is called potential gradient.

Circuit diagram of comparison of emf of two cells by potentiometer:-



Used formula:-

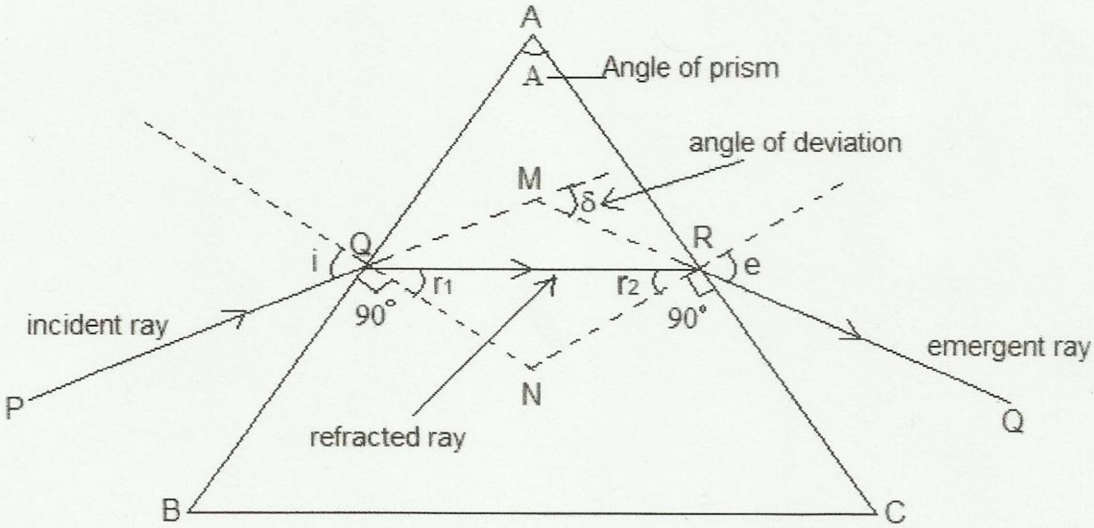
$$\frac{\varepsilon_1}{\varepsilon_2} = \frac{l_1}{l_2} \quad \text{................ (iii)}$$

The sensitivity of potentiometer can be increased by increasing length of potentiometer wire.

21. Draw a ray diagram showing the passes of light through a glass prism. Hence, obtained a relation between the angle of deviation, incidence, emergence and the angle of prism.

Answer:

Ray diagram of refraction of light through prism



Obtaining relation between refractive index of material of prism, angle of deviation and angle of prism

Angle of deviation:- The angle between emergent ray and incident ray produced is called angle of deviation.

In quadrilateral AQNR,

$\angle AQN + \angle ARN = 90^0 + 90^0 = 180^0$

$\therefore \angle A + \angle QNR = 180^0$ .... (i)

From triangle QNR,

$r_1 + r_2 + \angle QNR = 180^0$ .... (ii)

Comparing equation (i) and (ii), we get

$r_1 + r_2 = A$ .... (iii)

Again triangle angle δ is external angle of triangle MQR

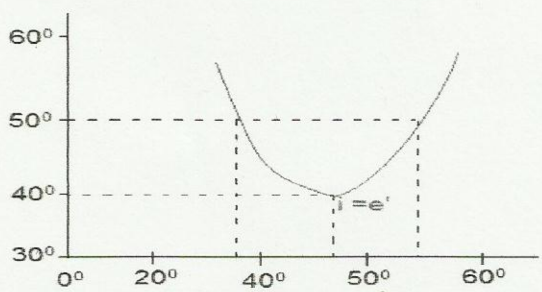
$\therefore \delta = \angle MQR + \angle MRQ = (\angle MQN - r_1) + (\angle MRN - r_2)$

$\Rightarrow \delta = (i - r_1) + (e - r_2) = (i + e) - (r_1 + r_2)$

$\Rightarrow \delta = i + e - A$ .... (iv) [from equation(iii)]

From this equation, it is clear that angle of deviation depends upon angle of incident.

The graph between angle of deviation and incident angle is shown in the figure-II. From graph it is clear that except i = e , i has two value for all values of δ and corresponding this e has two values. In case of minimum deviation refracted rays is parallel to the base of prism.



$\therefore$ on $\delta = D_m$, $i = e$ and $r_1 = r_2$

$\therefore$ from equation (iii),

$r + r = A \Rightarrow 2r = A \Rightarrow r = \frac{A}{2}$ .... (v) [let $r_1 = r_2 = r$]

Similarly, From equation (iii),

$D_m = i + i - A = 2i - A$

$\Rightarrow 2i = D_m + A \Rightarrow i = \frac{A + D_m}{2}$ .... (vi)

According to Snell's law, Refractive index of material of prism will,

$\mu = \frac{\sin i}{\sin r} = \frac{\sin\left[\left(\frac{A+D_m}{2}\right)\right]}{\sin[A/2]}$ .... (vii) [From equation (v) and (vi)]

For thin prism, D_m is also very small.

$\therefore$ from equation(vii),

$$\mu = \frac{\sin\left[\left(\frac{A+D_m}{2}\right)\right]}{\sin[A/2]} \approx \frac{\left(\frac{A+D_m}{2}\right)}{A/2}$$

$\Rightarrow \mu \times \frac{A}{2} = \frac{A + D_m}{2} \Rightarrow \mu A = A + D_m \Rightarrow \mu A - A = D_m$

$\Rightarrow D_m = A(\mu - 1)$ .... (viii)

22. (a) Deduce de Broglie wavelength of electron accelerated by a potential of V volt.
(b) An electron and a proton have same kinetic energy. Which of the two has larger wavelength and why ?

Answer:

(a) Suppose an electron of mass m and charge e is accelerated from rest by potential V. Doing this kinetic energy of electron would be equal to the work done acted by potential?

$\therefore$ Kinetic energy of electron,

$k = qV = eV$ .... (i)

Again, kinetic energy of electron,

$k = \frac{p^2}{2m} \Rightarrow p^2 = 2mk \Rightarrow p = \sqrt{2mk}$

$\Rightarrow p = \sqrt{2meV}$ .... (ii)

$\therefore$ De Broglie wavelength of electron,

$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2meV}}$ .... (iii)

In equation (iii) putting $h = 6.63 \times 10^{-34}$ Js , $m = 9.1 \times 10^{-31}$kg and $e = 1.6 \times 10^{-19}$ C we get.

$\lambda = \frac{6.63 \times 10^{-34}}{\sqrt{2 \times 9.1 \times 10^{-31} \times 1.6 \times 10^{-19}\, V}} = \frac{1.227}{\sqrt{V}}$ nm .... (iv)

(b) $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mk}} \Rightarrow \lambda \propto \frac{1}{\sqrt{m}}$ .... (v)

Since mass of electron is less than mass of proton. Therefore, wavelength (λ) of electron will greater than wavelength of Proton.

23. Rajiv lived in a metropolitan city. Some of his villagers came to visit. Rajiv decided to visit them by metro train. When they came to metro station, the secuirity guard asked

them to pass through a metal detector. They were scared of it. They decided not to travel by metro train. Rajiv explained them the purpose and working of metal detector. Then they ready for travelling.

(i) Draw the necessary circuit diagram.

(ii) What is a metal detector? How does it work?

Ans:

(a) presence of brain, higher degree of general awareness and helping nature.

(b) A metal detector is deigned by L-C circuit (a inductor and a capacitor connected in parallel). It works on the principle of resonance in an a.c. circuit.When a person passes through a metal detector ,it means he walks through a solenoid. If a person has any metal piece (knife, gun etc) , the impedance of circuit changes. This change causing a change in current through the circuit and an alarm can be activated.

Set – E

24. (a) Two long straight parallel conductors carrying steady current I_1 and I_2 separated by a distance d. Explain Briefly, with a help of suitable diagram how the magnetic field produced due to one conductor acts on the other. Hence deduce expression for force acting between the two conductors. Also define one ampere.

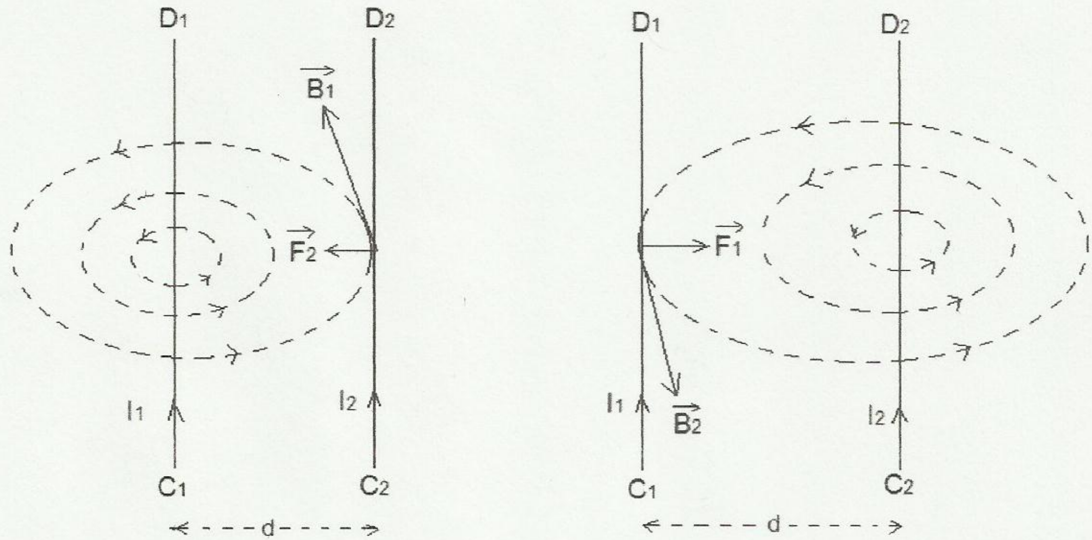
(b) A jet plane is travelling towards west at a speed of 1800 km/h. What is the voltage difference developed between the ends of the wing having a span of 25 m, if the Earth's magnetic field at the location has a magnitude of 5×10^{-4} T and the dip angle is 30°.

Or

(a) Explain with the help of a labeled diagram, the principle and working of an AC generator ? write the expression for the emf generated in the coil in term of speed of rotation. Can the current produced by an AC generator be measured with a moving coil galvanometer.

(b) How much current is drawn by primary coil of a transformer which steps down 220 V to 22 V to operate device with an impedance of 220 ohm.

Ans: (a)



Consider two parallel current carrying conductors C_1D_1 and C_2D_2 separated by distance d in air. Let current flowing through two conductors are I_1 and I_2 in same direction.

Now, Magnetic field due to conductor C_1D_1 at point P of conductor C_2D_2 will ,

, $B_1 = \frac{\mu_0}{4\pi}\frac{2I_1}{d}$ .... (i)

[$\because$ magnetic field near infinite straight conductor, $B = \frac{\mu_0}{4\pi}\frac{2I}{r}$]

Its direction is perpendicular to plane of paper and inwards.

Since second conductor is in magnetic field of first current carrying conductor. Therefore magnetic force per unit length on second conductor will,

$F_2 = I_2 l B_1$ [$\because F = I l B \sin\theta = I l B \sin 90^0 = I l B$]

$\Rightarrow F_2 = I_2 .1. B_1 = I_2 B_1$

$\Rightarrow F_2 = I_2 l \frac{\mu_0}{4\pi}\frac{2I_1}{d} = \frac{\mu_0}{4\pi}\frac{2I_1I_2}{d}$ [from equation (i)]

$\Rightarrow F_2 = \frac{\mu_0}{4\pi}\frac{2I_1I_2}{d}$ .... (ii)

Its direction is perpendicular to conductor C_2D_2 and in plane of paper along conductor C_1D_1.

Similarly, magnetic force per unit length on first conductor due to current in second conductor will,

$F_1 = \frac{\mu_0}{4\pi}\frac{2I_1I_2}{d}$ .... (iii)

Its direction is perpendicular to conductor C_1D_1 and in plane of paper along conductor C_2D_2.

From equation (i) and (ii),

$F_1 = F_2 = \frac{\mu_0}{4\pi}\frac{2I_1I_2}{d} = F$ (let) .... (iv)

Hence two parallel current carrying conductors attract to each other.

Similarly, it is proved that two anti parallel current carrying conductors repel to each other.

Definition of 1 ampere:-

$\because F = \frac{\mu_0}{4\pi}\frac{2I_1I_2}{d}$

$\Rightarrow F = 10^{-7}\frac{2I_1I_2}{d}$ .... (v)

If $I_1 = I_2 = 1$ A and $d = 1$ m, then from equation (v) ,

$F = 10^{-7}\frac{2\times1\times1}{1} = 2\times10^{-7}$ N

Hence, when two parallel current carrying conductors are placed in air at distance 1m and magnetic force acting between them is 2×10^{-7} N, then current in each conductor is called one ampere.

(b) Given, V = 1800 km/h = 500 m/s, l = 25 m, $B_E = 5\times10^{-4}$ T , $\delta = 30^0$, e = ?

$\therefore$ e = $B_V\, l\, V$ where B_V = vertical component of earth's magnetic field.

= $(B_E \sin\delta)\, l\, V$ = $5\times10^{-4}\times\sin30^0\times25\times500 = 625\times10^{-2}\times0.5$

$= 312.5\times10^{-2} = 3.13$ volt

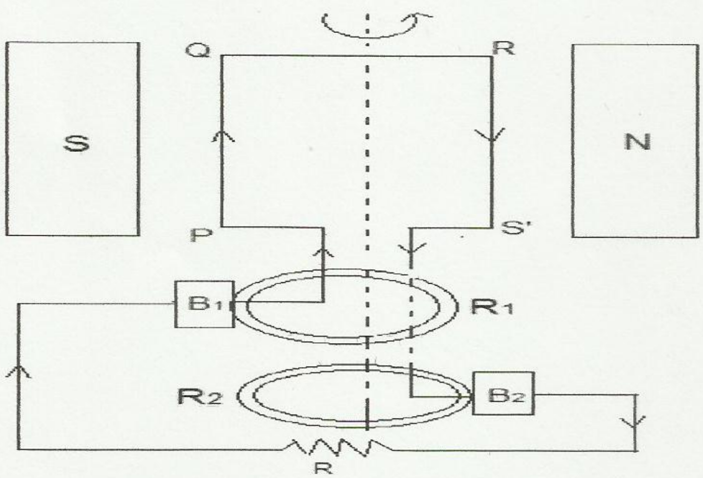
Or

Ans:

(a) A.C. generator:- It is device which converts mechanical energy into electric energy.

Priciple:- When magnetic flux linked with a coil changes with time then an electromotive force is induced in the coil.

Construction:-



It consists a rectangular coil PQRS' of insulated copper wire which turns on soft iron core. This is known as armature. Two slips ring R_1 and R_2 are fitted on ends of armature. Two carbon brushes B_1 and B_2 are in contact of R_1 and R_2 respectively. These carbon brushes are connected with conducting wire to the outer load.

Working:- when armature of generator is rotated by an external device, then magnetic flux linked with coil changes and an emf induces in the coil.

Suppose the coil rotates with angular velocity ω. Therefore angle between magnetic field vector **B** and area vector of coil at any instant will $\theta = \omega t$

∴ Magnetic flux linked with coil at any instant will,

$$\phi_B = BA \cos\theta = BA \cos\omega t \quad \ldots\ldots \text{(i)}$$

According to Faraday's law of electromagnetic induction, electromagnetic force induced in coil of N turns will,

$$\varepsilon = -N\frac{d\phi_B}{dt} = -N\frac{d(BA\cos\omega t)}{dt} = -NBA\frac{d(\cos\omega t)}{dt}$$

$$= -NBA(-\omega \sin\omega t) = NBA\omega \sin\omega t$$

Thus instantaneous value of induced emf is

$$\varepsilon = NBA\omega \sin\omega t \quad \ldots\ldots\ldots\ldots \text{(ii)}$$

$$\Rightarrow \varepsilon = \varepsilon_0 \sin\omega t \quad \ldots\ldots\ldots\ldots \text{(iii)}$$

Where $\varepsilon_0 = NBA\omega$ = maximum emf .... (iv)

$$\Rightarrow \varepsilon = \varepsilon_0 \sin 2\pi\nu t \quad \ldots\ldots\ldots\ldots \text{(v)} \ [\because \omega = 2\pi\nu]$$

Since value of sin function vary with time in between +1 and -1. Therefore direction of induced current vary with time. Hence current induced by an A.C. generator can not be measured by moving coil galvanometer.

(b) Given $V_P = 220$ volt, $V_S = 22$ volt, $R_S = 220$ ohm, $I_P = ?$

$$\therefore I_S = \frac{V_S}{R_S} \ [V = IR] = \frac{22}{220} = 0.1 \text{ A}$$

For an ideal transformer, $V_P \times I_P = V_S \times I_S$

$$\therefore I_P = \frac{V_S \times I_S}{V_P} = \frac{22 \times 0.1}{220} = 0.01 \text{ A} = 10^{-2} \text{ A}$$

25. (a) State Huygen's Principle. Using this principle draw a ray diagram to show how a plane waveform incident at the interface of two media gets refracted when it propagates from a rarer medium to a denser medium. Hence verify Snell's law of refraction.
(b) When monochromatic light travels from a rarer to a denser medium, explain the following, giving reasons:
(i) is the frequency of reflected and refracted light same as the frequency of incident light?

(ii) Does the decrease in speed imply a reduction in the energy carried by light wave?

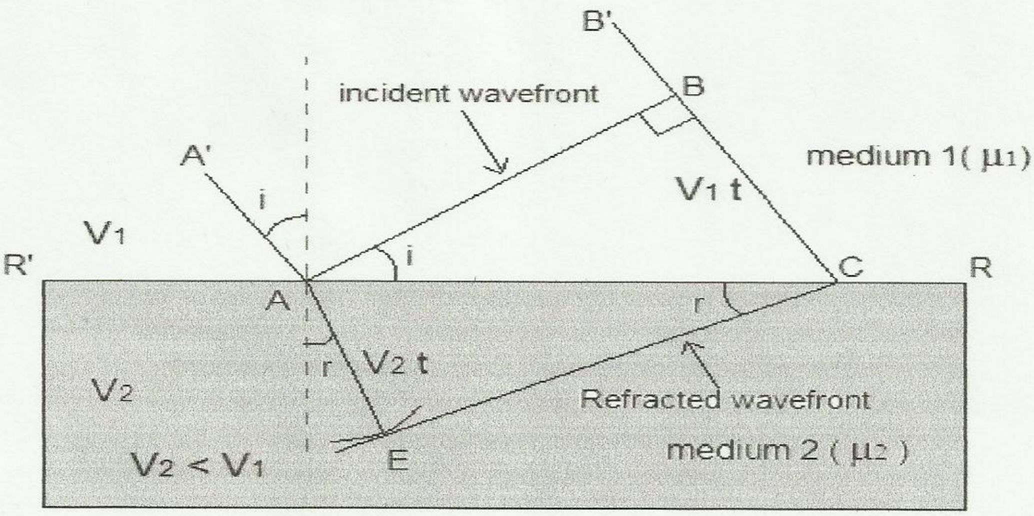
Or

(a) What is coherent sources of light.

(b) Show that in interference pattern all dark and bright fringes are of equal length.

Ans: (a)

Huygens principle:- each point of the wavefront is the source of a secondary disturbance and the wavelets emanating from these points spread out in all directions with the speed of the wave. These wavelets emanating from the wavefront are usually referred to as secondary wavelets and if we draw a common tangent to all these spheres, we obtain the new position of the wavefront at a later time.



Suppose a plane wavefront AB incidents on refracting surface RR' at an angle i and refracted at an angle r. The velocity of light in medium1 is V_1 and in medium 2 is V_2 , where $V_2 < V_1$. Let light reaches from B to C in time t.

$\therefore$ BC = $V_1 t$ .... (i)

To determine shape of refracted wavefront in medium 2 , draw tangent CE on point E. Thus obtained tangent CE is refracted wavefront.

$\therefore$ AE = $V_2 t$ .... (ii)

Now, in triangle ABC ,

$$\text{Sin } i = \frac{BC}{AC} = \frac{V_1 t}{AC} \quad .... \text{(iii)}$$

And in triangle ACE,

$$\text{Sin } r = \frac{AE}{AC} = \frac{V_2 t}{AC} \quad .... \text{(iii)}$$

$$\therefore \frac{Sin\, i}{\sin r} = \frac{V_1\, t}{V_2\, t} = \frac{V_1}{V_2} \quad .... \text{(iv)}$$

If refractive indices of medium 1 and 2 are μ_1 and μ_2 respectively and velocity of light in vacuum is c , then

$$\mu_1 = \frac{c}{V_1} \text{ and } \mu_2 = \frac{c}{V_2}$$

$$\therefore \frac{\mu_1}{\mu_2} = \frac{V_2}{V_1} \Rightarrow \frac{\mu_2}{\mu_1} = \frac{V_1}{V_2} \quad .... \text{(v)}$$

From equation (iv) and (v)

$\frac{Sin\ i}{\sin r} = \frac{\mu_1}{\mu_2}$ ……….. (vi)

This is Snell's law.

(b)

(i) If wavelength of light in medium 1 and 2 are λ_1 and λ_2 respectively, and distance BC is equal to the λ_1 , then distance AE will be equal to the λ_2.

$\frac{\lambda_1}{\lambda_2} = \frac{BC}{AE} = \frac{V_1 t}{V_2 t} = \frac{V_1}{V_2}$

$\Rightarrow \frac{V_2}{\lambda_2} = \frac{V_1}{\lambda_1} \Rightarrow v_2 > v_1$ [$\because c = v\lambda \Rightarrow v \frac{c}{\lambda}$]

Hence when light goes from a rarer medium to a denser medium ,then its speed decreases, but frequency is unchanged.

(ii) Since the frequency remains same, hence there is no reduction in energy.

Or

Ans:

Let d be the distance between two coherent sources A and B of wavelength λ. A screen XY is placed parallel to AB at a distance D from the coherent sources. O is the mid point of AB. C is a point on the screen equidistant from A and B , Where central bright fringe forms. P is a point on the screen at a distance x from C, as shown in Figure. Waves from A and B meet at Point P in phase or out of phase depending upon the path difference between two waves.

Draw AM perpendicular to BP

The path difference , δ = BP – AP ……. (i)

From figure AP = BP

$\therefore \delta =$ BP – MP = BM ………(ii)

In right angled Δ ABM, $\sin\theta = \frac{BM}{AB} \Rightarrow$ BM = AB $\sin\theta$ = d $\sin\theta$

If θ is small, then $\sin\theta = \theta$

$\therefore$ The path difference, $\delta = \theta.d$ ………….. (iii)

In right angled triangle COP, $\tan\theta = \frac{PC}{OC} = \frac{x}{D}$

For small values of θ, $\tan\theta = \theta$

$\therefore$ From equation (iii), $\delta = \frac{xd}{D}$ ……………. (iv)

Bright fringes:

For constructive interference on point P, path difference should be, $\delta = n\lambda$

$\therefore$ From equation (iv), $n\lambda = \frac{xd}{D}$

where n = 0,1,2 … indicate the order of bright fringes.

$\Rightarrow x = \frac{D}{d} n\lambda$ ………… (v)

This equation gives the distance of the nth bright fringe from the Point C.

Dark fringes:

For destructive interference on the point P, path difference should be, $\delta = (2n-1)\frac{\lambda}{2}$ where n = 1,2,3 … indicate the order of the dark fringes.

$\therefore$ From equation (iv), $(2n-1)\frac{\lambda}{2} = \frac{xd}{D}$

$\Rightarrow x = \frac{D}{d}(2n-1)\frac{\lambda}{2}$ ………… (vi)

This equation gives the distance of the nth dark fringe from the point C. Thus, on the screen alternate dark and bright bands are seen on either side of the central bright band.

Fringe Width (β):

The distance between any two consecutive bright or dark fringes is called fringe width.

$\therefore$ The distance between (n+1)th and nth of bright fringes from C is given by

$\beta = x_{(n+1)} - x_n = \frac{D}{d}(n+1)\frac{\lambda}{2} - \frac{D}{d}n\lambda = \frac{\lambda D}{d}(2n+1-n) = \frac{\lambda D}{d}$

$\therefore \beta = \frac{\lambda D}{d}$ ………. (vii)

Similarly, it can be proved that the distance between two consecutive dark fringes is also equal to $\frac{\lambda D}{d}$

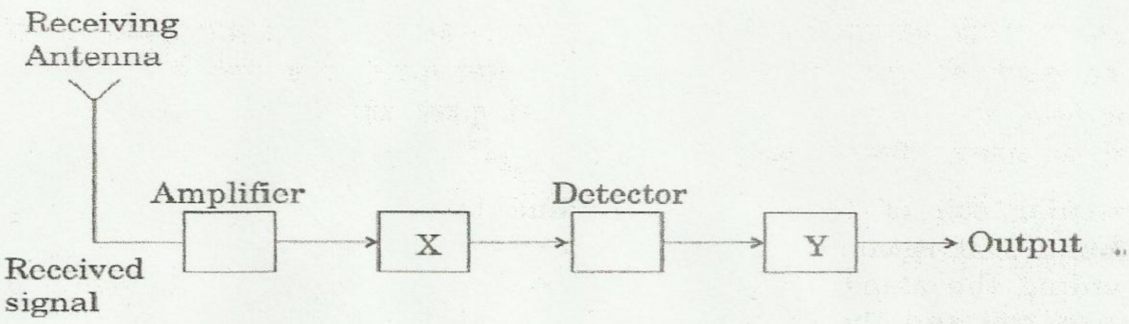
Hence all bright and dark fringes are of equal length.

26. (a) What is Zener diode. Draw its symbol and V-I characteristic curve.
(b) Why is zener diode fabricated by heavily doping both p- and n-sides of the junction ?
(c) Draw the circuit diagram of zener diode as a voltage regulator and briefly explain its working

OR

(a) Explain conductors, insulators on the basis of Band theory.

(b) In the given block diagram of a receiver, identify the boxes labelled as X and Y and write their function

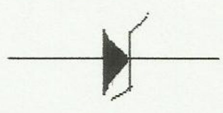


Answer:-

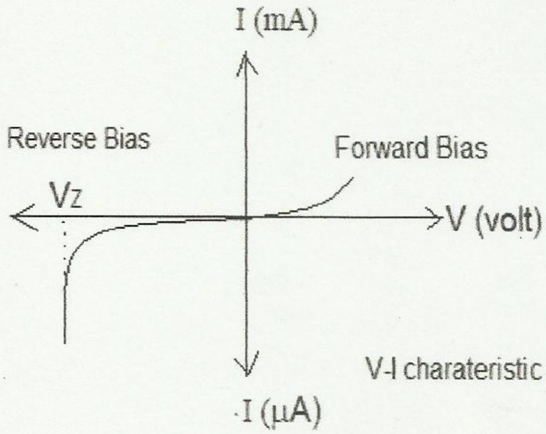
(a) Zener Diode:

It is a special purpose semiconductor diode, named after its inventor C. Zener. It is designed to operate under reverse bias in the breakdown region and used as a voltage regulator. The symbol for Zener diode is shown in Fig-1.

(b) Zener diode is fabricated by heavily doping both p and n- sides of the junction. Due to this, depletion region formed is very thin ($<10^{-6}$ m) and the electric field of the junction is extremely high ($\sim 5\times10^{6}$ V/m) even for a small reverse bias voltage of about 5V.



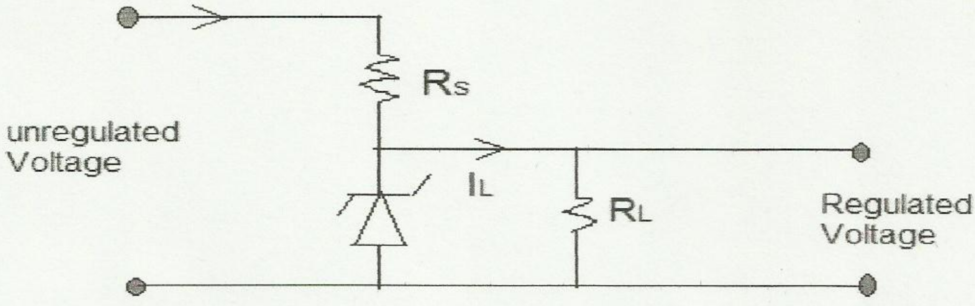
Symbol of Zener diode



V-I charateristic curve

The I-V characteristics of a Zener diode is shown in Fi-2. It is seen that when the applied reverse bias voltage(V) reaches the breakdown voltage (Vz) of the Zener diode, there is a large change in the current. Zener voltage remains constant, even though current through the Zener diode varies over a wide range. This property of the Zener diode is used for regulating supply voltages so that they are constant.

Zener diode as a voltage regulator



when the ac input voltage of a rectifier fluctuates, its rectified output also fluctuates. To get a constant dc voltage from the dc unregulated output of a rectifier, we use a Zener diode. The circuit diagram of a voltage regulator using a Zener diode is shown in Fig-3. The unregulated dc voltage (filtered output of a rectifier) is connected to the Zener diode through a series resistance *Rs* such that the Zener diode is reverse biased. If the input voltage increases, the current through *Rs* and Zener diode also increases. This increases the voltage drop across *Rs* without any change in the voltage across the Zener diode. This is because in the breakdown region, Zener voltage remains constant even though the current through the Zener diode changes. Similarly, if the input voltage decreases, the current through *Rs* and Zener diode also decreases. The voltage drop across *Rs* decreases without any change in the voltage across the Zener diode. Thus any increase/ decrease in the input voltage results in, increase/ decrease of the voltage drop across *Rs* without any change in voltage across the Zener diode. Thus the Zener diode acts as a voltage regulator.

Or

(a) Conductor, semiconductor and Insulator on the basis of energy bands:.

Conductors:

The energy band diagram for a conductor is such that either the conduction band is partially filled with electrons or the conduction and valence band partly overlapped each other and there is no forbidden energy gap in between. In both the situation, it can be considered that the conductor has a single energy band which is partly filled and partly empty. In this situation, large number of electrons are available for electrical conduction. Hence the resistance of conductor is very low or the conductivity is very high.

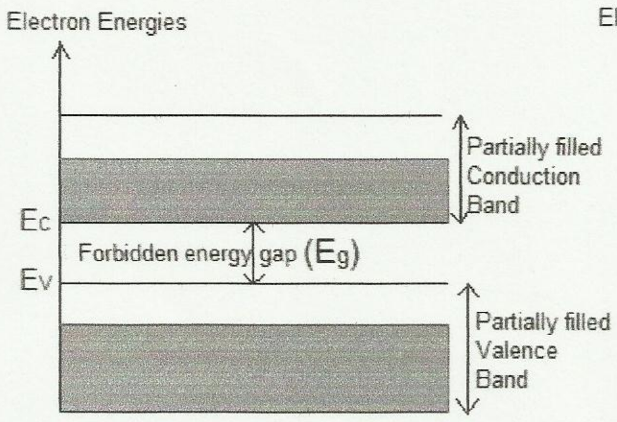


Fig - 1 (a)

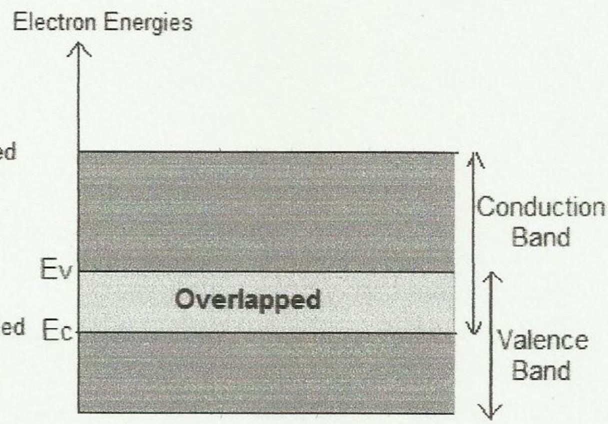


Fig - 1 (b)

Insulators:

The energy band diagram of insulator is shown in the figure-2. Here, the valence band is completely filled, the conduction band is empty and energy gap is quite large (E_g>3 eV). Due to large energy gap, no electrons is able to go from the valence band to the conduction band even electric field is applied. Hence electrical conduction in insulator is impossible.

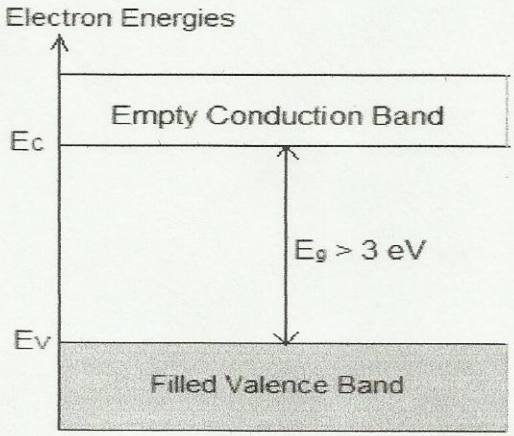


Fig - 2

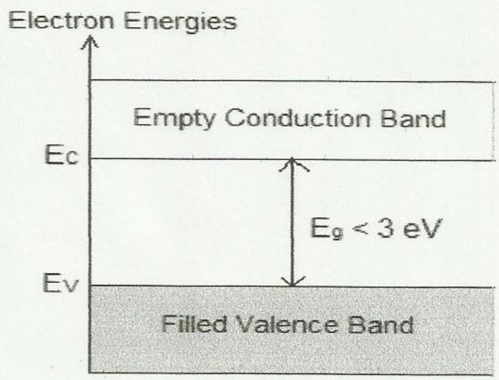


Fig - 3

Semiconductors:

The energy band diagram of semiconductor is shown in the figure-3. Here the valence band is totally filled and the conduction band is empty but the energy gap between conduction band and valence band is quite small. It is less than 3 eV. For example energy gap for germanium is 0.72 eV and for silicon it is of 1.1 eV.

At zero Kelvin temperature, electron are not able to cross even this small energy gap and hence the conduction band remains tatally empty. Therefore, the semiconductor at zero Kelvin behaves as insulators.

(b) Ans:

X- This represents IF stage. It convert carrier wave into intermediate frequency so that information signal can be separate from carrier wave.

Y- It represents amplifier. It amplify (increase of amplitude) weak signal separated by carrier wave.